Downloaded from orbit.dtu.dk on: May 05, 2023

DTU Library

Radiometric Measurements of Environmental Radioactivity

Beta Counting, Alpha and Gamma Spectrometry

Nielsen, Sven Poul

Publication date:
2013

Link back to DTU Orbit

Citation (APA):
Nielsen, S. P. (Author). (2013). Radiometric Measurements of Environmental Radioactivity: Beta Counting, Alpha and Gamma Spectrometry. Sound/Visual production (digital)
http://www.nks.org/en/seminars/presentations/nks-b_radioanalysis_workshop_2-6_september_2013.htm

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

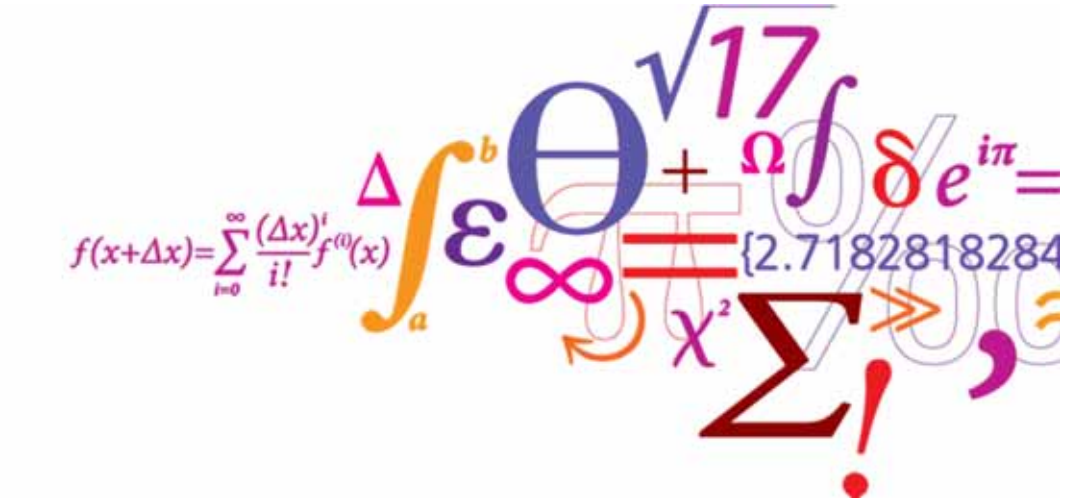
- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Radiometric Measurements of Environmental Radioactivity

Beta Counting, Alpha and Gamma Spectrometry

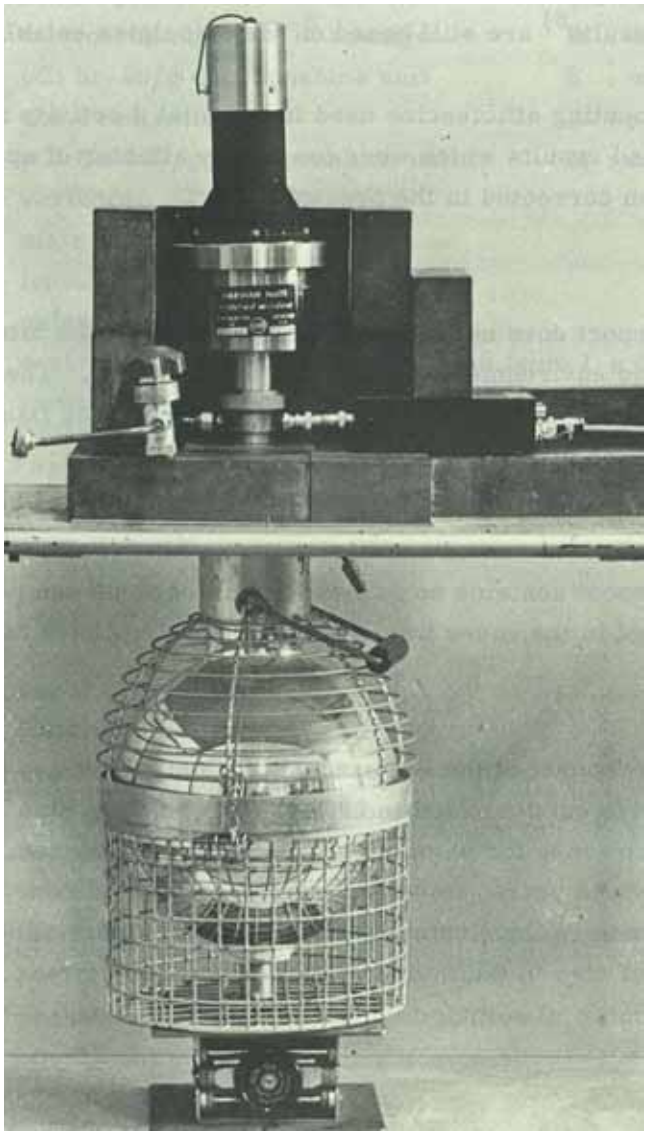
Sven Nielsen



DTU Nutech
Center for Nuclear Technologies

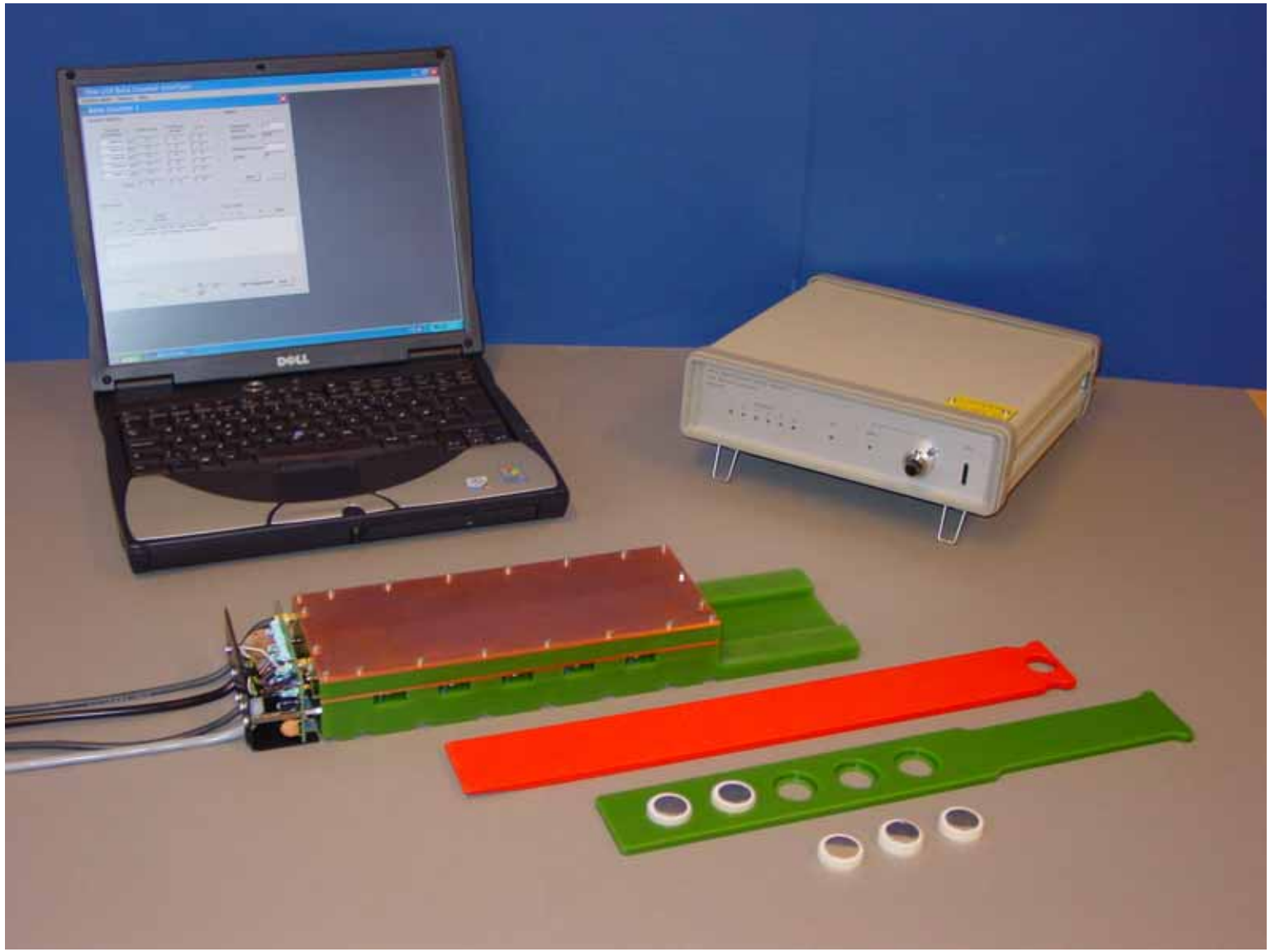
Early start at Risø

- Measurements of environmental radioactivity started at Risø in 1956 using Geiger-Müller equipment (e.g. Anton Electronic Laboratories, New York)
- Alpha/beta measurements using proportional counters from 1960
- Gamma spectrometry (air filters) started in 1960 using a 4-inch NaI well detector and a 100-channel pulse height analyzer
- Gamma spectrometry using small Ge(Li) detectors (e.g. 2 cm^3) made at Risø started in 1965 with 1024 channel analyzers
- Alpha spectrometry using Si detectors and 256-ch MCAs from 1968
- Commercial Ge(Li) detectors used from 1974, own production stopped



1966 Compton rejection setup

Risø Low-Level Beta GM Multicounter

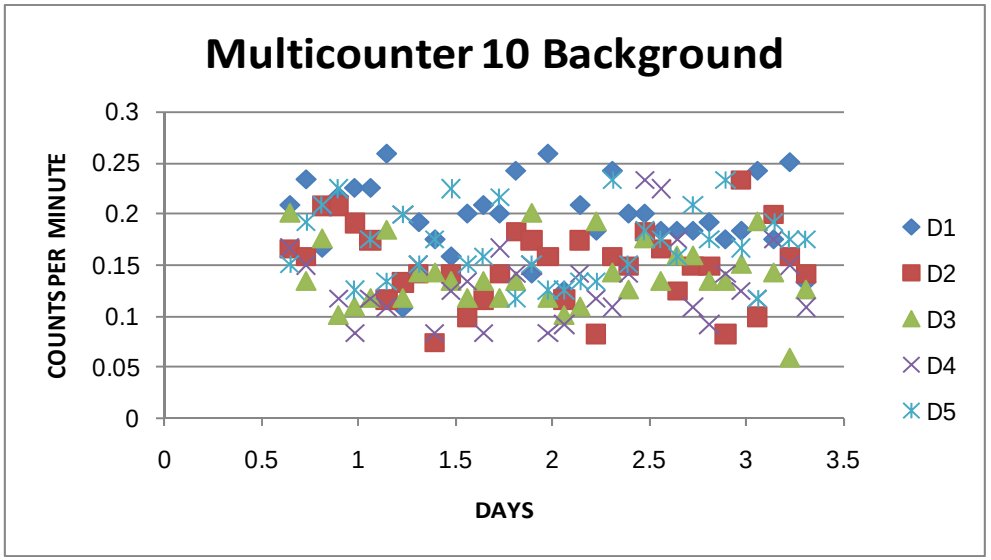


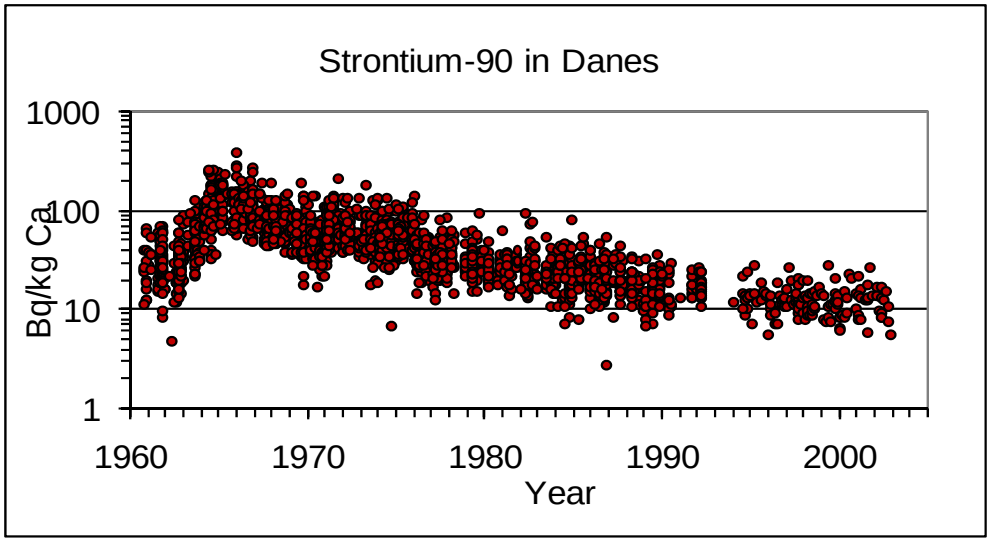
Description

- Low-level gas-flow beta multicounter for simultaneous measurements of 5 samples.
- Incorporates 5 individual counter elements and a common guard counter
- Guard counter uses anti-coincidence technique to reduce background from cosmic radiation by more than a factor 700
- Aluminized Mylar window of thickness less than 1 mg/cm^2
- Counter gas 99% Ar / 1% isobutane or propane
- Counter placed in 10-cm lead shield

Specifications and Applications

- Multicounters used for total beta counting of ^{90}Sr and ^{99}Tc
- Guard count rates typically about 2 cps
- Detector background count rates typically about 0.2 cpm
- Detector efficiencies checked monthly using reference sources, ^{36}Cl and ^{99}Tc
- Counting efficiencies about 58% for ^{90}Y sources mounted on steel cores and about 40% for ^{99}Tc sources on steel disks
- Detection limits for routine applications about 2 mBq for ^{90}Sr and 4 mBq for ^{99}Tc
- Results from spreadsheet calculations



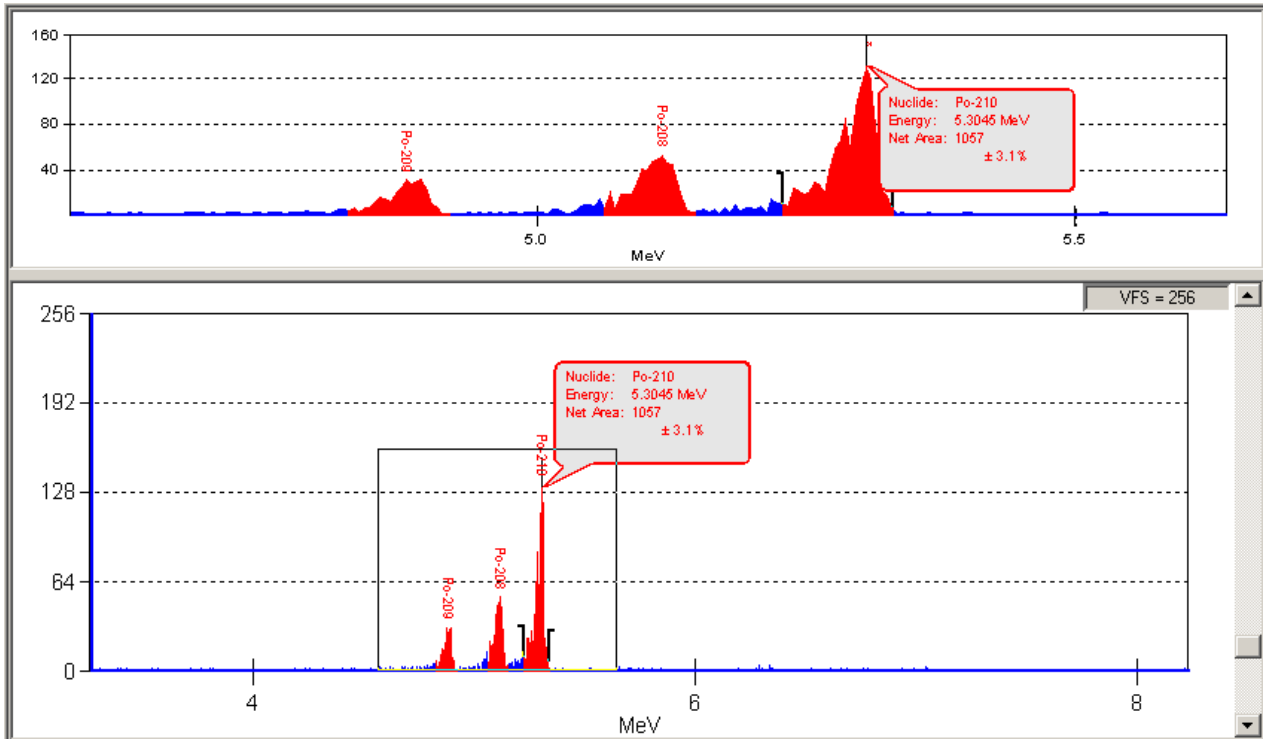


Alpha Spectrometry

Risø Vacuum Chamber

Description

- 32 Si detectors
- Vacuum chambers made at Risø
- 20 mm diameter sources electrodeposited on stainless steel disks
- Counting times typically 3-7 days
- Detection limits 0.1-0.2 mBq
- Results from spreadsheet calculations
- Analyses of Po, U, Pu, Am, (Np)



Gamma Laboratory

Lead Shields

Ge Detector Specifications

Risø id.	Producer	Year	Efficiency	Fwhm (keV)	Other
1	Ortec	1986	38%	1.8	1.3 mm Al window
2	Ortec	1986	35%	1.8	1.3 mm Al window
3	Ortec	1986	33%	1.9	Low energy, 0.5 mm Be window
4	Ortec	1986	33%	1.9	Low energy, 0.5 mm Be window
5	Canberra	1987	35%/180 cm^3	2.0	Low energy, Mg well, low background
6	Canberra	1998	118 cm^3	1.8	Low energy, 0.5 mm carbon epoxy, low background
7	Canberra	2001	260 cm^3	2.3	Low energy, Al well, low background
414	PGT	1979	25%	1.8	Ge(Li)
423	PGT	1978	27%	2.0	Ge(Li)
952	Ortec	1995	37%	1.8	Low energy, 0.5 mm Be window, low background

Electronics

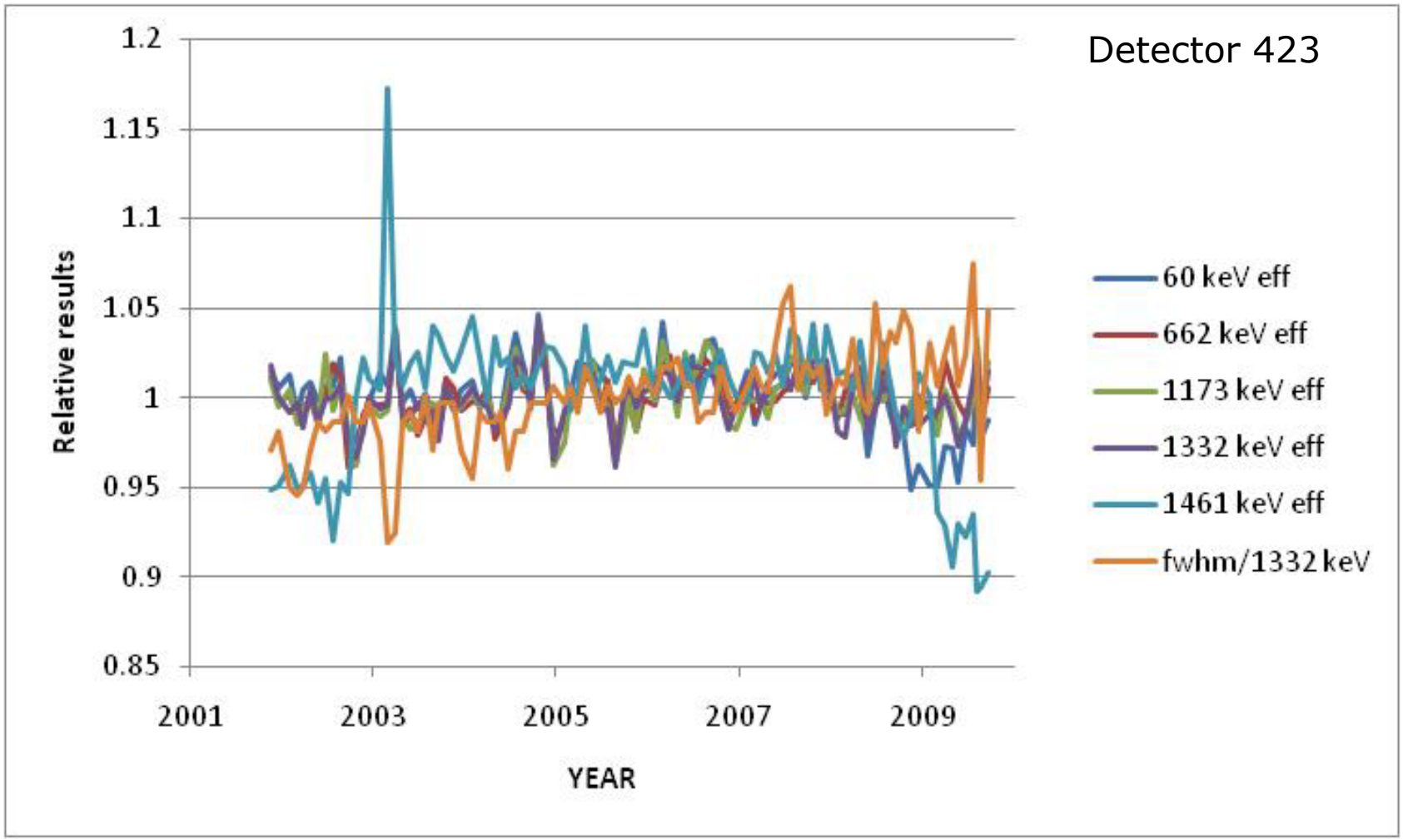
DTU Nutech, Technical University of Denmark

Sample Geometries

- 1-L Marinelli beaker (1 L)
- 210 mL cylindrical beaker (range 20-200 mL)
- 25 mL Petri dish (5, 10 and 15 mL)
- 10 mL vial (range 1-8 mL)
- 2 mL vial (range 0.2-2 mL)

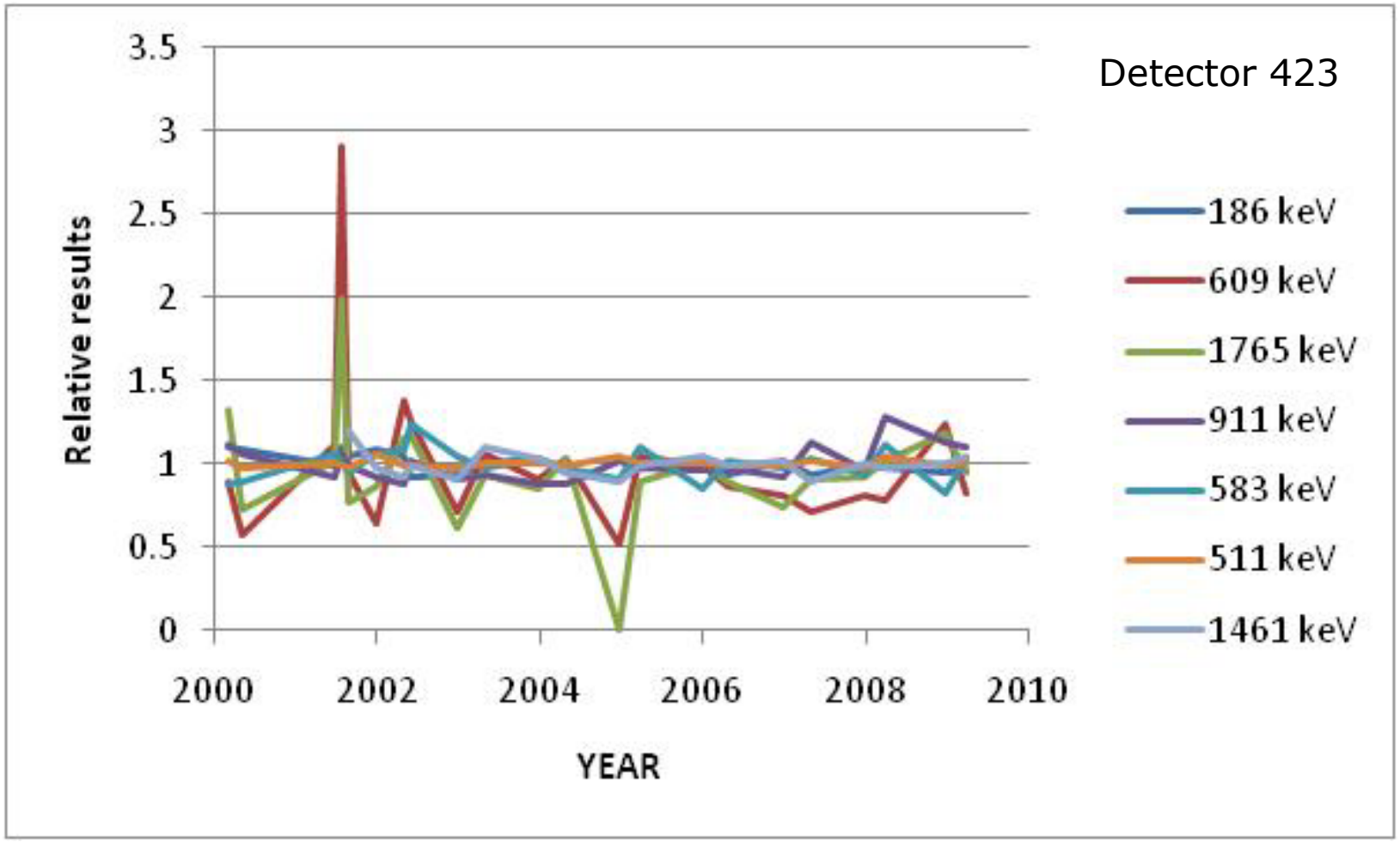
Detector Efficiency and Energy Resolution

- Effeciency and energy resolution of detectors checked monthly with reference sources ^{241}Am, ^{137}Cs, ^{60}Co and ^{40}K



Detector Gamma Background

- Ge detector background counts performed during prolonged holidays, i.e. Easter and Christmas



Software for Gamma Spectrum Analysis

- Home made software, developed since 1970's, implemented first in Algol programming language on main-frame computer, later in C on personal computer
- Peak search based on values of second derivative of smoothed spectrum
- Peak area calculation based on simple summation of smoothed spectrum counts over peak channels minus background, fitting of doublets
- Accuracy of peak-area calculation method compared with other procedures (1998)

```
--------- Måling nr. 405486 ---------
1: Sample type: Milk
2: Date       : 2009-Aug
3: Location   : W-Jutland 3
6: Sample ID  : 20090327
Res.el.vægt:             2.0000  kg dry
1: Detektor   :        4,       4
2: Måleperiode: 20090812.1138,20090817.0847
3: Fyldning   :            -0.4000
4: Vægtfylde  :             0.6100
5: Energikal. :   2.0606,  0.6687
6: Måletid    :            421797
Spektrum: 4000 kanaler
TOPAREAL fil A -> B, t = 1.5, max.eta = 40 %
 41 - 5979 kan., delta = 2.5 keV
  br. fra kalib.  w1: 5, w2: 13, udglat = 3
 Isotoptabel indeholder 140 isotoper
Milk from Videbæk august 2009
Spektrum nr. 405486, detektor 4, kalibrering 4
Kan: KeV:   w:(w0) b: Bagg: Eta: cps*1000: Eta: Bq(100%)  Vfk.: Bq(vf):
438761  510.6  7295.0  6( 6) 1.2 1.81  9.9     -0.22 100.0
439( 7) 2.525.41  1.0   5.25  11.2     0.303 0.932     0.283 ( 3)
 907  608.9  7( 7) 1.9 2.96  5.5     -0.09 100.0
 986  661.2  7( 7) 1.6              10.14   4.4     0.739 0.940     0.695 ( 4)
2180 1459.8  9( 9) 2.2 2.81  3.7    655.66   0.2    92.579 0.958    88.733 ( 6)
2634 1763.0 10(10) 2.9 0.87  9.6     -0.13 100.0
3905 2613.4 13(13) 3.1 1.69  4.5      0.00 100.0
-----------------------
```

Sample output

Tests of accuracy versus that of data set no. 4

Data no.	Software	Type	DF	T	χ^2-Reduced	Sign.
1	CompAct	Simple	21	15.9	0.76	ns
2	GammaVision	Simple	21	202	9.62	***
3	GammaVision	Simple	21	195	9.29	***
4	GammaVision	Simple	21	21.9	1.04	ns
5	Genie-PC	Simple	21	40.0	1.90	*
6	Genie-PC	Simple	21	38.5	1.83	*
7	C-Base	Simple	21	38.2	1.82	*
8	Genie-PC	Fitting	21	18.4	0.88	ns
9	GAMANAL	Fitting	20	32.1	1.61	ns
10	GRILS	Fitting	20	269	13.5	***
11	EMCAPLUS	Fitting	21	11.0	0.52	ns
12	ANSP	Fitting	21	9.8	0.47	*
13	GammaTrac	Fitting	21	21.0	1.00	ns
14	GammaTrac	Fitting	21	53.9	2.57	***
15	GAMMA-96	Other	21	19.1	0.91	ns

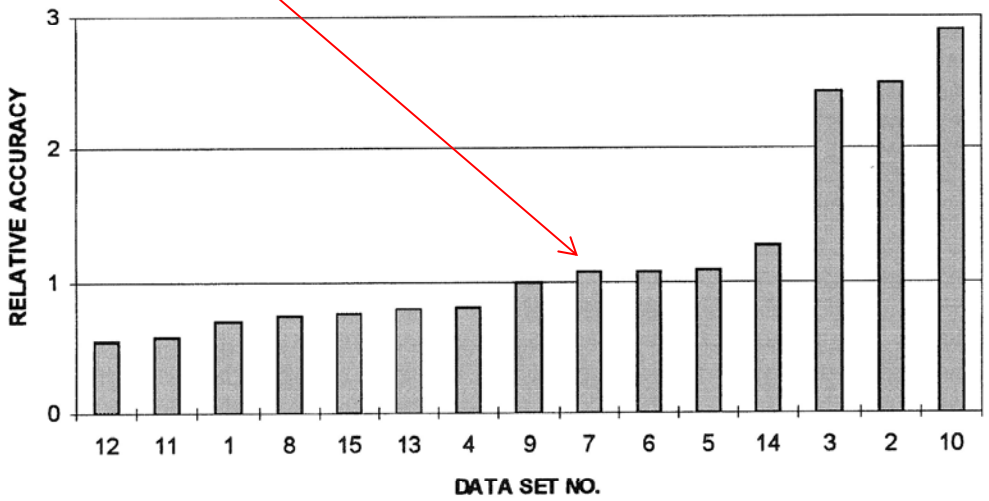
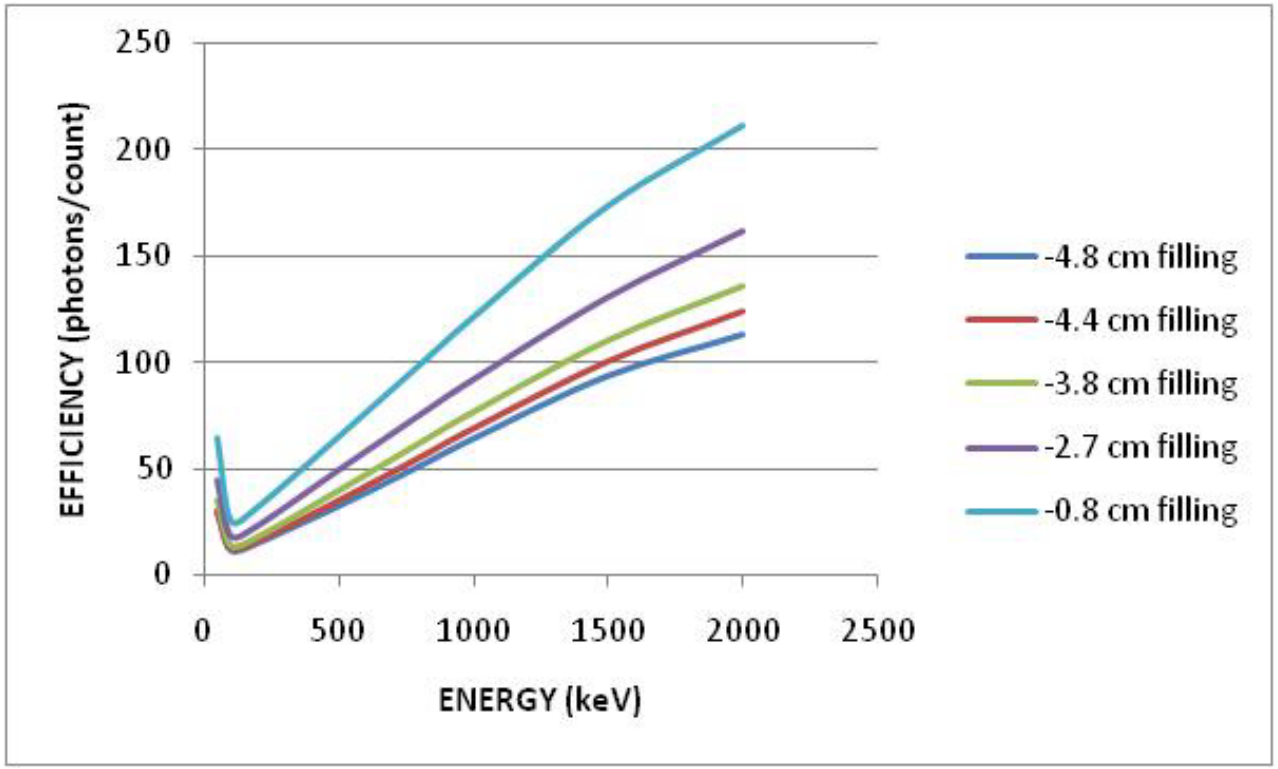


Fig. 3. Plot of relative average accuracies of peak-area ratios for the data sets.

Efficiency Calibration

- Calibrations based on measurements in standardized geometries of known activities of mixed radionuclide gamma-ray reference solutions and K_2CO_3 standard, e.g. ^{241}Am, ^{109}Cd, ^{57}Co, ^{139}Ce, ^{51}Cr, ^{113}Sn, ^{85}Sr, ^{137}Cs, ^{88}Y and ^{60}Co
- Calibration curves fitted to measured efficiencies (photons/count) using polynomial expressions



Detector 423 efficiency calibration

True Coincidence Summing Correction

- True coincidence summing correction factors determined experimentally as deviations between observed efficiencies and calibration curves

Nuclide	Energy (keV)	-4.8 cm filling	-4.4 cm filling	-3.8 cm filling	-2.7 cm filling	-0.8 cm filling
57Co	122	0.98	0.99	0.99	0.99	1.00
57Co	136	0.93	0.89	0.93	0.96	0.95
60Co	1173	1.00	1.00	1.00	1.00	1.00
60Co	1332	0.99	0.99	1.00	1.00	0.99
134Cs	605	1.18	1.17	1.15	1.14	1.15
134Cs	796	1.13	1.13	1.11	1.10	1.11
134Cs	802	1.22	1.23	1.21	1.18	1.18
226Ra	186	0.47	0.47	0.49	0.48	0.46
226Ra	352	1.05	1.04	1.07	1.04	1.04
226Ra	609	1.17	1.16	1.16	1.15	1.14
226Ra	1765	0.95	0.95	1.00	0.99	0.99

Excerpt of coincidence summing correction factor table for five different fillings of the 210 mL geometry for detector 423

Density Correction

- Density correction based on a mathematical model of Ge detector, sample geometry and density (Lippert 1983)
- Correction factor CF calculated as

$$CF = e^{\rho - 1} \cdot xabs \cdot e^{m_0 - m_1 ln E_\gamma}$$

- Where ρ is sample density, xabs characteristic length for sample geometry, m_0 and m_1 constants, and E_γ gamma energy.
- Example correction factors

Gamma energy (keV)	210 mL cylinder 178 mL	210 mL cylinder 59 mL
100	1.33	1.13
500	1.14	1.06
1000	1.10	1.04
1500	1.08	1.03

- Furthermore, for measurements of ^{210}Pb at 47 keV, correction for self absorption is applied by experimental determination of attenuation using a ^{210}Pb point source

Commercial software for gamma analysis

- Using Genie2000 for single application under formal QA/QC
  - Test of radiometric purity of eluate from $^{99}Mo/^{99m}Tc$ generator
- Advantages of commercial software
  - More user friendly and with better future prospects than home made software
  - Features and documentation prepared for formal QA/QC
  - Documentation available

Future

- Full use of Genie2000 software